RESHAPING THE WAY WE LOOK AT GENERAL AVIATION ACCIDENTS USING THE HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM

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As part of the FAA's endeavor to better understand the cause of general aviation (GA) accidents, we previously analyzed nine years (1990-98) of fatal GA accident data using the Human Factors Analysis and Classification System (HFACS). The findings, though significant, reflected only about 20% of the total GA accidents that occurred during the time period examined. Therefore, an analysis of the remaining non-fatal accidents was conducted to provide a more complete picture of the human factors associated with GA accidents. Using HFACS, five pilots independently coded the cause factors associated with 14,571 GA accidents that occurred between 1990-99. Overall, skill-based errors (primarily technique errors) were associated with nearly four out of every five GA accidents since 1990, followed by decision errors (37%) and perceptual errors (less than 10%) regardless of whether the accident resulted in a fatality. On the other hand, violations of the rules were more common among fatal (32%) than non-fatal (10%) accidents. Finally, there was little difference between FAA geographic regions in the types of unsafe acts committed by GA pilots involved in accidents. Furthermore, there appeared to be no differences in the Alaska region as compared to the rest of the U.S. when using HFACS. These analyses provide unique insight into the genesis of GA accidents. Implications for GA initial and recurrent training are discussed.

Introduction

Understandably, a great deal of effort has been expended over the last several decades to improve safety in both military and civilian aviation. Yet, even though hundreds of people have died and millions of dollars in assets have been lost, the numbers pale by comparison to those suffered every year within general aviation (GA). Take the decade of the 90's for example. For every commercial or military accident that occurred in the U.S., roughly nine GA aircraft crashed (Table 1). More alarming, nearly one in five GA accidents (roughly 400 per year) involved fatalities, including 7,074 deaths. Since 1990, no other form of aviation has taken more lives.

Why then has general aviation received so little attention? Perhaps it has something to do with the fact that flying has become relatively commonplace as literally millions of travelers board commercial aircraft daily to get from place to place. Not surprising then, when a commercial airliner crashes, it instantly becomes headline news, shaking the confidence of the flying public. As a result, the public is more interested in commercial aviation than GA. In turn, the government has focused a great deal of their limited aviation resources on improving commercial aviation safety.

But does the commercial accident record warrant the lion's share of the attention it has received? Well, if you consider the data in Table 5.1, there are about 130 commercial aircraft accidents per year. However, of these 130 "accidents," many were simply minor injuries due to turbulence or involved small, on-demand air taxis. Very few were on the scale of TWA Flight 800, the Boeing 747 that crashed off the coast of New York in July of 1996 killing all 230 passengers and crew. In fact, of the 1,309 commercial airline accidents that occurred in the 90's, only a handful involved major air carriers and fewer yet were associated with fatalities.

On the other hand, GA accidents happen virtually every day yet they receive little attention and seldom appear on the front page of *USA Today*. Perhaps this is because they happen in isolated places, involving only a couple of hapless souls at a time. In fact, unless the plane crashed into a school, church, or some other public venue, it is very unlikely that anyone outside the local media, government, or those intimately involved with the accident even knew it happened.

Even though GA safety may not be on the cusp of public consciousness, a number of studies of GA accidents have been conducted in an attempt to understand their causes. Unfortunately, most of these efforts have focused on contextual factors or pilot demographics rather than the underlying causes of the accidents. While no one disagrees that contextual factors like weather (e.g., IMC versus VMC), lighting (e.g., day versus night), and terrain (e.g., mountainous versus featureless) contribute to

Table 1. The number of accidents annually for U.S. commercial, military, and general aviation.

Year	Commercial	USN/USMC	USA	USAF	Totals	GA
1990	146	63	32	51	292	2,241
1991	137	59	43	41	280	2,197
1992	117	57	25	48	247	2,111
1993	108	43	22	34	207	2,063
1994	118	31	15	35	199	2,022
1995	125	30	10	32	197	2,056
1996	138	40	8	27	213	1,908
1997	147	25	16	29	217	1,845
1998	135	33	10	24	202	1,904
1999	138	27	18	30	213	1,906
Totals	1,309	408	199	351	2,267	20,253

Source: U.S. Naval Safety Center, U.S. Army Safety Center, U.S. Air Force Safety Center, and NTSB.

accidents, pilots have little, if any, control over them. Likewise, knowing a pilot's gender, age, occupation, or flight experience, contributes little to our ability to prevent GA accidents. After all, just because males may have a higher accident rate than females, or pilots with fewer that 500 flight hours have a higher risk of accidents, what are we to do? Can we restrict males from flying or require pilots to have more than 500 flight hours before they are granted a certificate?

This information has provided little in the way of preventing accidents, apart from identifying target audiences for the dissemination of safety information. In fact, even when the leading cause of accidents, human error, has been addressed, it is often only to report the percentage of accidents associated with aircrew error in general or to identify those where alcohol or drug use occurred.

What is needed is a thorough human error analysis. However, previous attempts to do just that have met with limited success (O'Hare, Wiggins, Batt, & Morrison, 1994; Wiegmann & Shappell, 1997). This is due primarily to the fact that human error is influenced by a variety of factors that are usually not addressed by traditional classification schemes (Shappell & Wiegmann, 1997). Yet, with the development of the Human Factors Analysis and Classification System (HFACS) previously unknown patterns of human error in aviation accidents have been uncovered (Shappell & Wiegmann, 2000, 2001a; Wiegmann & Shappell, 2001a). For a complete description of the HFACS framework see Shappell and Wiegmann, 2001b.

In a previous study, we analyzed nine years (1990-98) of fatal GA accident data using the HFACS framework (Wiegmann & Shappell, 2001b). The findings, though significant, reflected only about 20% of the total GA accidents that occurred during the time period examined. Therefore, the purpose of the present study was to analyze the remaining non-fatal accidents in order to provide a more complete picture of the human factors associated with GA accidents.

Methods

Data

General aviation accident data from calendar years 1990-99 was obtained using databases maintained by the NTSB and the FAA's National Aviation Safety Data Analysis Center (NASDAC). In total, 19,864 GA accidents were extracted for analysis. These so-called "GA" accidents actually included a variety of aircraft being flown under several different operating rules: 1) 14 CFR Part 91 – Civil aircraft other than moored balloons, kites, unmanned rockets, and unmanned free balloons; 2) 14 CFR Part 91F – Large and turbine-powered multiengine airplanes; 3) 14 CFR Part 103 – Ultralight vehicles; 4) 14 CFR Part 125 – Airplanes with seating capacity of 20 or more passengers or a maximum payload capacity of 6,000 pounds or more; 5) 14 CFR Part 133 – Rotorcraft external-load operations; 6) 14 CFR Part 137 – Agricultural aircraft operations. In addition, the database contained several accidents involving public use aircraft (i.e., law enforcement, state owned aircraft, etc.). The distribution of each of these accident categories within the NTSB/NASDC databases is presented in Table 2.

As one might expect, we were concerned with the heterogeneity of the accident sample as depicted in Table 2 since we were only interested in those accidents involving aircraft operating under 14 CFR Part 91. After all, it is difficult to envision that large commercial aircraft being ferried from one airport to the next (operating under 14 CFR Part 91F) or aircraft being used to spread chemicals on a field (operating under 14 CFR Part 137) can be equated with small private aircraft being flown for personal or recreational purposes (operating under 14 CFR Part 91). This left us with 18,239 accidents in the database.

Table 2. Distribution of accidents using the NTSB and FAA NASDAC general aviation databases.

Type of operation	Frequency
14 CFR Part 91	18,239
14 CFR Part 91F	8
14 CFR Part 103	12
14 CFR Part 125	2
14 CFR Part 133	136
14 CFR Part 137	1,411
Public Use	56
Totals	19,864

Next, the accidents were examined for aircrew-related causal factors. Again, we were only interested in those involving aircrew error, not those accidents that were purely mechanical in nature or those with other human involvement. This does not mean that mechanical failures or other sources of human error did not exist in the final database, only that some form of aircrew error was also involved in each of the accidents included in the final database. In the end, 14,571 accidents involving over 33,000 aircrew causal factors were included and submitted to further analyses using the HFACS framework.

<u>Causal Factor Classification using HFACS</u>

Five GA pilots were recruited from the Oklahoma City area as subject matter experts and received roughly 16 hours of training on the HFACS framework. All five were certified flight instructors with a minimum of 1,000 flight hours in GA aircraft (mean = 3,530 flight hours) as of June 1999 when the study began. After training, the five GA pilot-raters were randomly assigned accidents so at least two separate pilot-raters analyzed each accident independently. Using narrative and tabular data obtained from the NTSB and the FAA NASDAC, the pilot-raters were instructed to classify each human causal factor using the HFACS framework. Note, however, that only those causal factors identified by the NTSB were classified. That is, the pilot-raters were instructed <u>not</u> to introduce additional casual factors that were not identified by the original investigation. To do so would be presumptuous and only infuse additional opinion, conjecture, and guesswork into the analysis process.

After our pilot-raters made their initial classifications of the human causal factors (i.e., skill-based error, decision-error, etc.) the two independent ratings were compared. Where disagreements existed, the corresponding pilot-raters were called into the laboratory to reconcile their differences and the consensus classification was included in the database for further analysis. Overall, pilot-raters agreed on the classification of causal factors within the HFACS framework more than 85% of the time (29,534 agreements; 4519 disagreements), an excellent level of agreement considering that this was, in effect, a decision-making task. [Note that the measure of agreement was a combined analysis of all accidents coded under the NTSB classification of "general aviation" and therefore includes accidents other than 14 CFR Part 91 as described above. A breakout by 14 CFR Part 91 alone was not possible at this time but there is no reason to believe that the level of agreement would change appreciably.]

Results and Discussion

<u>Fatal versus Non-fatal GA Accidents</u>

Let us first look at the roughly 3,200 fatal GA accidents associated with aircrew error. From the graph in Figure 1, some important observations can be made. For instance, it may surprise some that skill-based errors, not decision errors, were the number one type of human error associated with fatal GA accidents. In fact, accidents associated with skill-based errors (averaging roughly 82% across the years of the study) more than doubled the percentage of accidents seen with decision errors (36%) and the willful violation of the rules (32%). Even perceptual errors, the focus of a great deal of interest over the years, were associated with less than 12% of all fatal accidents.

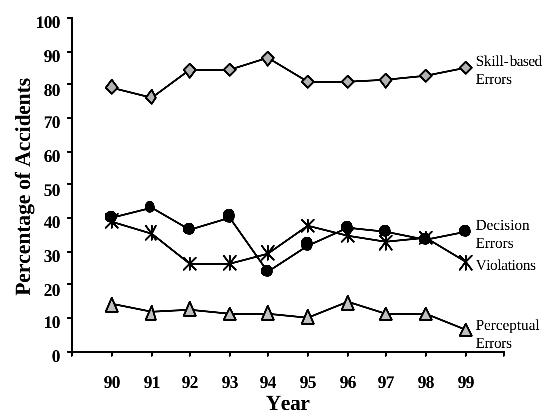

Figure 1. Percentage of fatal GA accidents associated with each unsafe act.

Also noteworthy was the observation that the trend lines are essentially flat. This would seem to suggest that safety efforts directed at GA over the last several years have had little impact on any specific type of human error. If anything, there may have been a general, across-the-board, effect, although this seems unlikely given the safety initiatives employed. The only exceptions seemed to be a small dip in the percentage of accidents associated with decision errors in 1994 and 1995 and a gradual decline in violations observed from 1991 to 1994. In both cases however, the trends quickly re-established themselves at levels consistent with the overall average.

While this is certainly important information, some may wonder how these findings compare with the nearly 11,000 non-fatal accidents. As can be seen in Figure 2, the results were strikingly similar to those associated with fatalities. Again, the trends across the years were relatively flat and as with fatal accidents, skill-based errors were associated with more non-fatal accidents than any other error form, followed by decision errors, violations, and perceptual errors respectively.

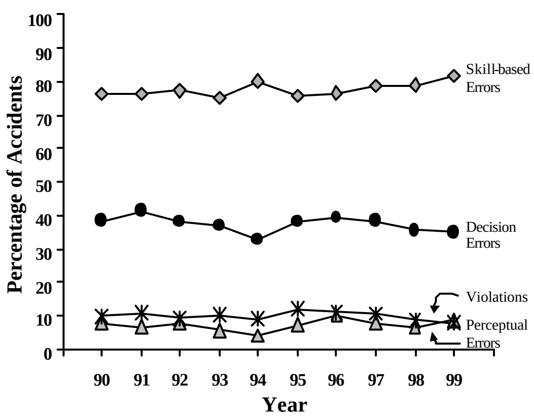

Figure 2. Percentage of nonfatal GA accidents associated with each unsafe act.

When the error trends are plotted together for fatal and non-fatal GA accidents, as they are in Figure 3, it is readily apparent that the proportion of accidents associated with violations was considerably less for non-fatal than fatal GA accidents. In fact, using a common estimate of risk known as the odds ratio, fatal accidents were at least four times more likely to be associated with violations than non-fatal accidents (odds ratio = 4.314; 95% confidence interval = 3.919 to 4.749, Mantzel-Haenszel test for homogeneity = 985.199, p<.001). Put simply, if a violation of the rules resulting in an accident occurs, you are considerably more likely to die or kill someone else than get up and walk away.

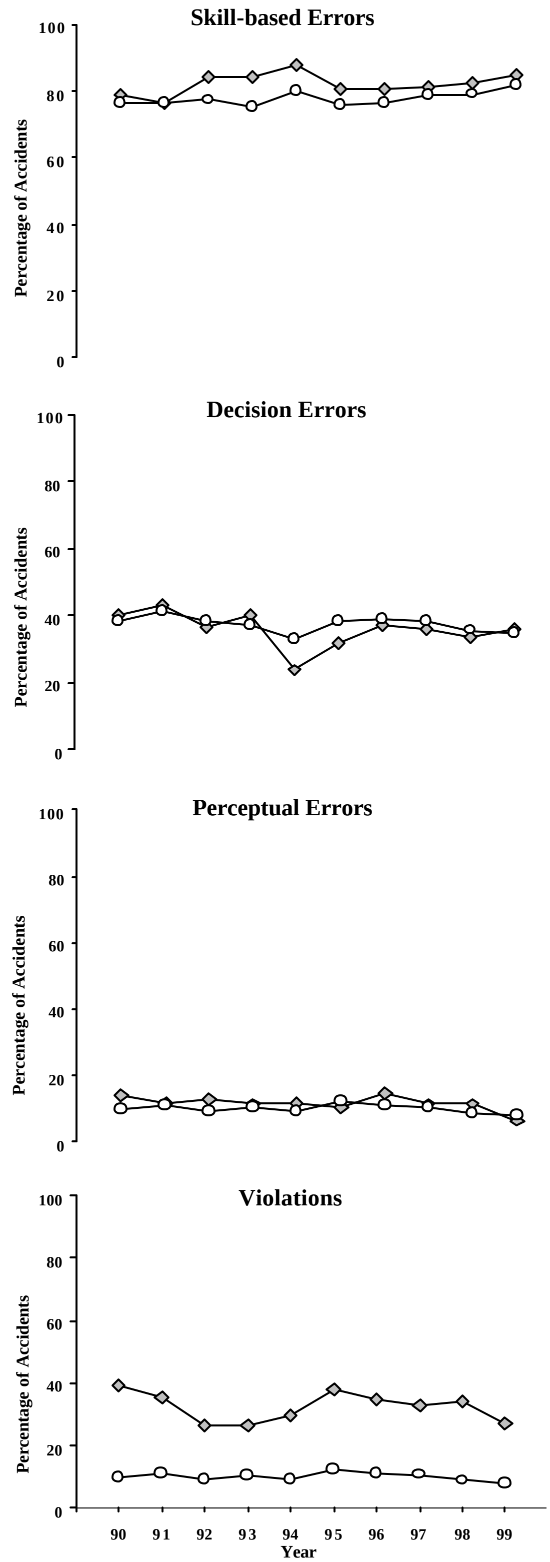

Figure 3. Percentage of fatal (closed-diamonds) and nonfatal (open circles) GA accidents associated with each unsafe act.

FAA Regional Analysis

Of particular interest to those involved with GA safety and training programs was the possibility that differences exist in the types of errors committed by GA pilots across geographic regions of the country. For instance, one might assume that given the often harsh terrain and weather conditions experienced by pilots in Alaska, differences might exist when they were compared with their counterparts in the rest of the U.S. Indeed, some have made that very argument for years – albeit based upon anecdotes and conjecture rather than the accident record. Unfortunately, until now opinion and anecdotes were about all we had to work with. But with the development of HFACS and the completion of the GA analysis, we now have a systematic and scientific means to address this issue.

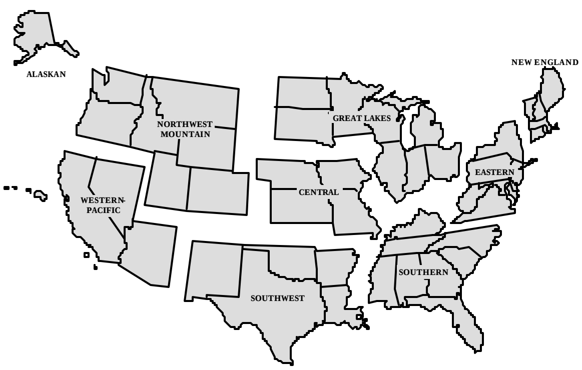

Figure 4. FAA Regions

So, with this in mind, we parsed the data set by the region where the accident occurred using the existing FAA regional breakout. The FAA is divided into nine regions as presented in Figure 4. While one can certainly question whether putting Hawaii in with California, Nevada, and Arizona makes sense or question why one state was considered part of Region X but not Region Y or Z, we chose to work within existing FAA regions.

Much to the surprise of some, we saw no differences between FAA regions in the relative distribution of errors and violations committed by GA pilots involved in accidents (Figure 5). Even Alaska appears similar to the rest of the U.S. when the data are examined systematically.

Apparently, whether and accident occurred in Alaska or Florida, California or New York, the relative distribution of unsafe acts (errors and violations) committed by aircrew is strikingly similar. Indeed, even those that espouse the "bush pilot" theory of flying in Alaska seem to be off base. While Alaska may witness more accidents, which in turn may be more a function of the fact that folks in Alaska fly aircraft like we take taxis in the continental U.S. Regardless, the types of errors committed by pilots do not appear to vary.

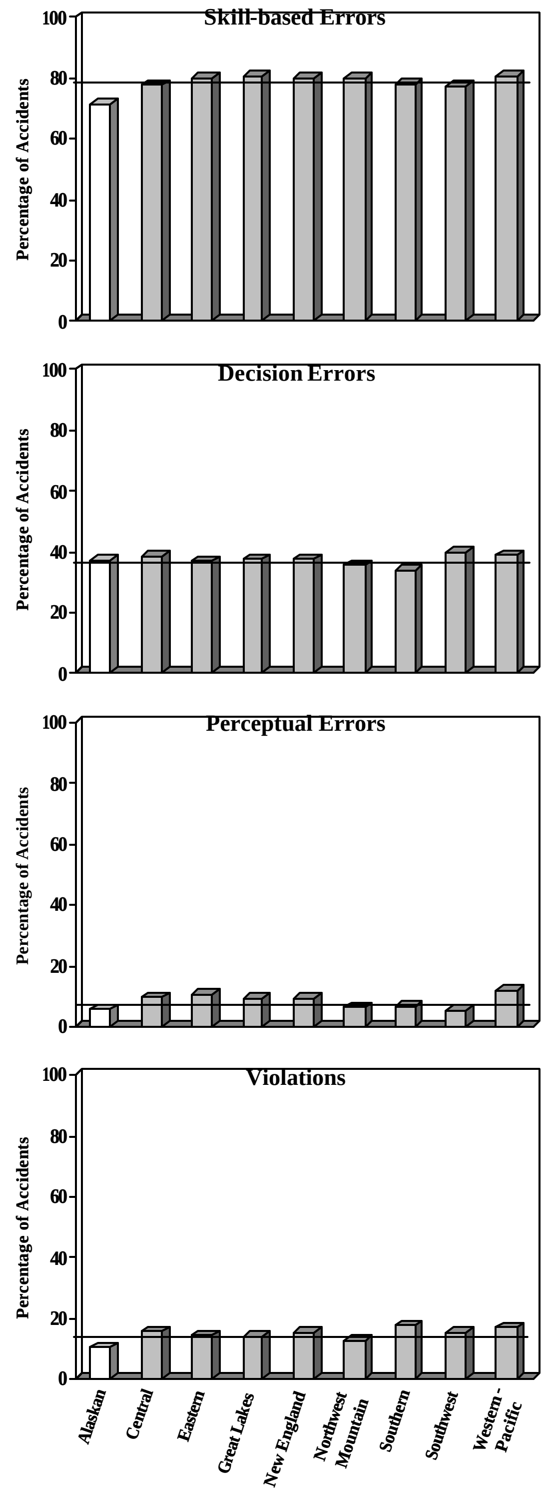

Figure 5. Regional analysis of unsafe acts by FAA region (Alaska region is in white).

Conclusions

So, what does all this mean? For the first time ever, we can talk about more than just the fact that nearly 80% of all general aviation accidents are attributable to "human error." After all, would you continue see a physician who only confirmed that you were "sick" without telling you what was wrong or what was needed to make you better? Probably not. The good news is that we now know "what is wrong" with general aviation – at least from a human error point of view. Specifically, the vast majority of GA accidents, regardless of severity, are due to skill-based errors. Also evident from our analyses, one-third of fatal accidents are due to violations of the rules and they are much less common in non-fatal accidents.

All of this leads to the inevitable question, "what can be done now that the face of human error has been exposed within GA?" Well, the data does suggest some possible avenues for preventing accidents. For example, there is a need to address the large percentage of accidents associated with skill-based errors. Perhaps placing an increased emphasis on refining basic flight skills during initial and recurrent flight training could possibly be effective in reducing skill-based errors. However, if the goal is to reduce fatal accidents, then greater emphasis must also be placed on reducing the number of violations through improved flight training, safety awareness, and enforcement of the rules.

Nevertheless, before such interventions can be effectively applied, several other questions concerning the nature and role of human error in aviation accidents need to be addressed. The following are a just a couple of the questions we are currently addressing:

- What are the exact types of errors committed within each error category? In other words, how often do skill-based errors involve stick-and-rudder errors, verses attention failures (slips) or memory failures (lapses)?
- How often is each error type the "primary" cause of an accident? For example, 80% of accidents might be associated with skill-based errors, but how often are skill-based errors the "initiating" error or simply the "consequence" of another type of error, such as decision errors?

Once these questions have been adequately addressed, then interventions can be developed to prevent or mitigate GA accidents

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